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Effects of Light Availability on Survival and Growth of Seedling and Sapling of Tropical Dry Deciduous Forest Tree Species in Ballavpur Wild Life Sanctuary, West Bengal, India

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Abstract: Seasonal variation of available light under tree canopy could impact growth and survival of tree seedlings and saplings in tropical dry forest. Different species responds differentially to such natural traits. The seedling and sapling growth and survival of six dry forest tree species under two different canopy conditions were studied inside the Ballavpur Wild Life Sanctuary. Light intensity significantly differed under open and closed canopy stands. Seedling survival varied for different species and ranged from 60-100%. No seedling and sapling of *Butea monosperma* and *Terminalia arjuna* were available under closed and open canopy respectively. The seedling survival was independent of the canopy condition but significantly varied for different species. Relative growth rate in height (RGRH) of tree seedlings differed significantly among different species.The seasonal rainfall in the dry deciduous forest promoted the relative growth of tree seedlings. The present study emphasized that species specific response plays very important role in governing the seedling survival and growth of tropical dry deciduous tree species.

Keywords: Dry deciduous forest, Canopy condition, Light availability, Relative growth, Seedling and sapling survival

Canopy cover is the layer formed by the branches and crowns of plants or trees. The cover can be continuous, as in primary forests, or discontinuous - with gaps. The forest canopy is a structurally complex and ecologically important subsystem of the forest. Forest canopy is an important ecological parameter of forest ecosystem for its relationship with natural regeneration and species richness (Zollner and Crane 2003). Due to its primary importance in photosynthesis, light limits the tree-seedling recruitment under various forest canopies (Way and Pearcy 2012). The early establishment phase in the life cycle of trees is influenced by the presence and abundance of understorey (Rodríguez-García et al 2011).The influence of light on the tree seedlings growth in tropical ecosystem has been well documented (Turner 2001, Vieira and Scariot 2006a, Tripathi and Raghubanshi 2014). Seasonal variation in understorey light availability has a vital role in shaping the establishment and growth of tree seedlings in tropical dry forest (Tripathi and Raghubanshi 2014). In tropical dry forests understorey light levels are relatively high, due to a more open and lower canopy compared to moist forests (Holbrook et al 1995, Murphy and Lugo 1986, Coomes and Grubb 2000). Seedlings generally grow slowly under high canopy or deep shade relatively utilizes less or no added nutrients to the soil (Baker et al 2003a). In India the influence of canopy cover on vegetation in *Pinus* dominated forests in Uttrakhand were studied by Arya and Ram (2016). Singh et al (2008) studied the impact of different tree species canopy on diversity and productivity of understorey vegetation in Indian desert. Tripathi et al (2020) showed the effects of light availability on seedling growth in a tropical dry forest of Uttar Pradesh. Effect of canopy cover on understory invasive alien species in the Wayanad Wildlife Sanctuary, Kerala was studied by Najar and Rahim (2018). Though several studies have been done in other parts of India, only a few remote sensing forest canopy estimations are available from West Bengal (Bera et al 2021, Pal et al 2018). Studies on seedling and sapling growth under different canopy conditions are also lacking. So this work has been undertaken to study the growth of seedlings and saplings of few selected dry deciduous tree species under different canopy conditions.

MATERIAL AND METHODS

Study area: This study was carried out in the Ballavpur Wildlife Sanctuary of Birbhum district in West Bengal. This sanctuary is managed within the jurisdiction of Bolpur Range under Birbhum Forest Division of South East circle. It extends between 23°39'25"N latitude and 87°41'39"E longitude (Fig. 1). It represents the Bio-geographic zone 7BChhotonagpur Plateau. During the summer, the temperature can shoot well above 40 °C (104 °F) and in winter it can drop to around 10 °C (50 °F). The annual average rainfall is 1,212 millimetres (47.7

in), mostly in the monsoon months (June to September). The sanctuary has natural Sal forests. In 1954-55 Acacia, Sissoo, Cashew nut and other trees were planted to green the barren land. Sanctuary has three water bodies (locally called Jhils) which attract large number of winter migratory birds.

Measurement of light intensity: The selection of species was done as par with method of Nag and Gupta (Joshi) (2020). Two stands differing in light conditions (open and closed canopy) were selected in the Ballavpur WLS. Digital Lux Meter (Model LX-101A, Taiwan) was used to measure light intensity below the tree canopy (Tripathi et al 2020). The light intensity was measured four times in a year at interval of three months from November 2018 to August 2019. Light intensity was measured at the same time of the day in both open and close canopy stands.

Estimation of relative growth rate in terms of height (RGRH): Variable numbers of natural regenerations (1 to 16 seedlings and saplings depending upon their availability) were identified and tagged for the six selected species under both stands in November 2018. Each stand was visited at the end of three months corresponding to three seasons (winter, summer and rainy), and the number of tagged seedlings and saplings surviving for each species were counted and their growth in heights was measured by a meter tape. Relative growth rate in terms of height (RGRH) was estimated as:

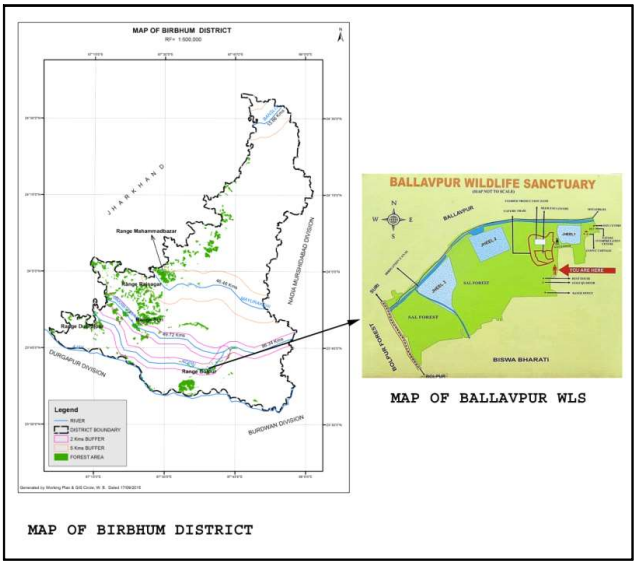

Fig. 1. Study area (Source: www.westbengalforest.gov.in)

$$\text{RGRH} = \text{Log}\ \frac{\text{Final height}}{\text{Initial height}} \div \text{Time intervals in days}$$

Statistical analysis: Chi-square test of independence was done to find whether there is significant association between seedling survival and canopy condition. Chi-square tests for goodness of fit were done to find whether seedling survival varied among the six species and under the two canopy conditions. Variations in light intensity and RGRH were analysed with SPSS, version 20.

RESULTS AND DISCUSSION

Light Intensity under open and closed canopy: The light intensity ranged from 9500 to 72100 lux under open canopy condition and from 610 to 11100 lux under close canopy condition (Table 1). Highest light intensity was recorded in May under open canopy and lowest value in February. In closed canopy highest and lowest light intensity were in August and February, respectively. Light intensity was significantly different under open and closed canopy conditions. However, light intensity did not vary significantly in different seasons. Interaction of canopy condition and seasons was also not significant. In the dry tropical environments the survival and growth of the tree seedlings are intensely determined by light availability (Poorter 2001, Khurana and Singh 2006, Tripathi and Raghubanshi 2014).

Seedling and sapling survival under open and closed canopy: Seedling survival varied for different species and ranged from 60-100% (Fig. 2). A single seedling of *Butea monosperma* was tagged under open canopy condition while maximum number of seedlings and saplings (16) were tagged for *Terminalia arjuna* under closed canopy condition. No seedling and sapling of *Butea monosperma* and *Terminalia arjuna* were available under closed and open canopy respectively. All the tagged seedlings and saplings of *Buchanania lanzan* and *Terminalia arjuna*under closed canopy and of *Butea monosperma* under open canopy survived throughout the study period. Lowest survival was noticed for *Terminalia bellirica* under closed canopy with 6 out of 10 seedlings surviving through the study period.

A Chi-square test of independence revealed that seedling survival of selected species was independent of canopy condition and varied significantly among different species when both canopy conditions were combined. However,

Table 1. Light intensity range under open and close canopy in different time periods

Canopy condition	Light Intensity (Lux)			
	November	February	May	August
Open canopy	10900-45000	9500- 53600	19600- 72100	10200- 51000
Close canopy	760- 6200	610- 9410	1100- 7300	900- 11100

when all the species were combined, the seedling survival did not vary under two canopy conditions. Out of the six selected species, seedlings of light demanding *Butea monosperma* were absent under close canopy while of shade tolerant *Terminalia arjuna* were absent under open canopy; rest four species survived under both open and closed canopy conditions. This indicates that different species respond differently to the canopy condition in terms of regeneration. The seedling survival also indicates the overall regeneration status of the species. Good seedling survival of *Terminalia arjuna* and *Buchanania lanzan* in Ballavpur WLS correlates with their good regeneration status in our previous study on population and regeneration status (Nag and Gupta (Joshi) 2020).

Many studies observed higher seedling survival under open and partially open conditions than under closed canopy condition (Nanda and Mohanty 2010, Castro-Marin et al 2011). Promoting effect on seedling survival by canopy gaps benefited light demanding species more than the shade tolerant species (Lu et al 2018). Low light intensity, poor spectral quality, increased fungal attack through increased humidity, physical damage due to litterfall, concealment for seedling predators, soil and microsite conditions, etc., are cited for reduction in seedling survival under close canopy (Castro-Marin et al 2011, Tripathi and Raghubanshi 2014). Contrary to the above, many studies reported better growth of seedlings under close canopy due to certain advantages given by the adult trees – allowing the access to higher soil moisture for longer periods to the understory tree seedlings Phillips and Barnes 2002, Bertacchi et al 2016) due to hydraulic lift (Ludwig et al 2004). Competition by grasses may also suppress the tree-seedling growth under open canopy (Kambatuku et al 2011). These might be the reasons for our observation on survival and growth of *Terminalia arjuna* seedlings and saplings under close canopy only. *Terminalia arjuna* is a shade-tolerant late successional species with large seeds having reduced germination in canopy openings (Khurana and Singh 2004).

RGRH under open and closed canopy: *Phyllanthus emblica* showed better RGRH under open canopy than under closed canopy in all the seasons whereas *Pterocarpus marsupium* showed better RGRH under closed canopy in all the seasons (Fig. 3). All the species had highest RGRH in the rainy season under both open and close canopy.

Relative growth rate (RGRH) differed significantly among different species but did not vary significantly under open and closed canopy. However interaction of species and canopy conditions on relative growth rate was significantly different. *Phyllanthus emblica* showed higher RGRH under open than under closed canopy while *Pterocarpus marsupium* showed

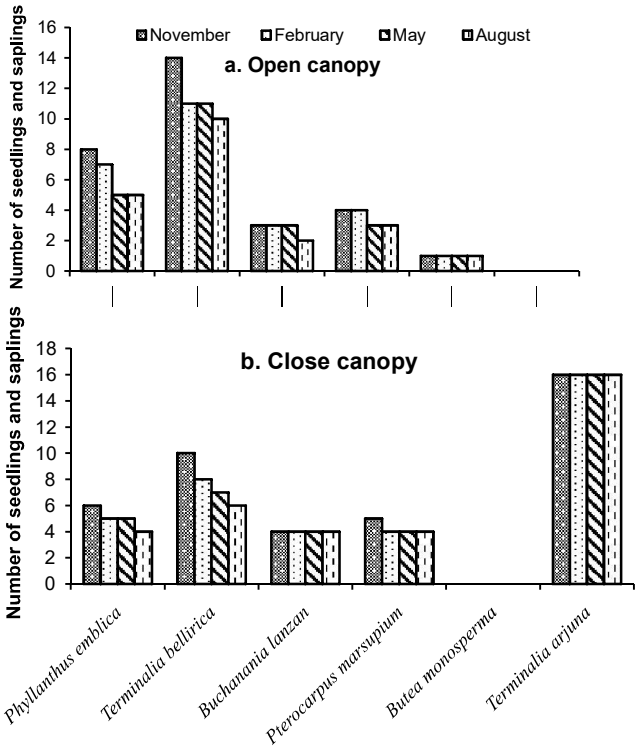

Fig. 2. Survival of seedlings and saplings of different species under (a) open and (b) closed canopy conditions

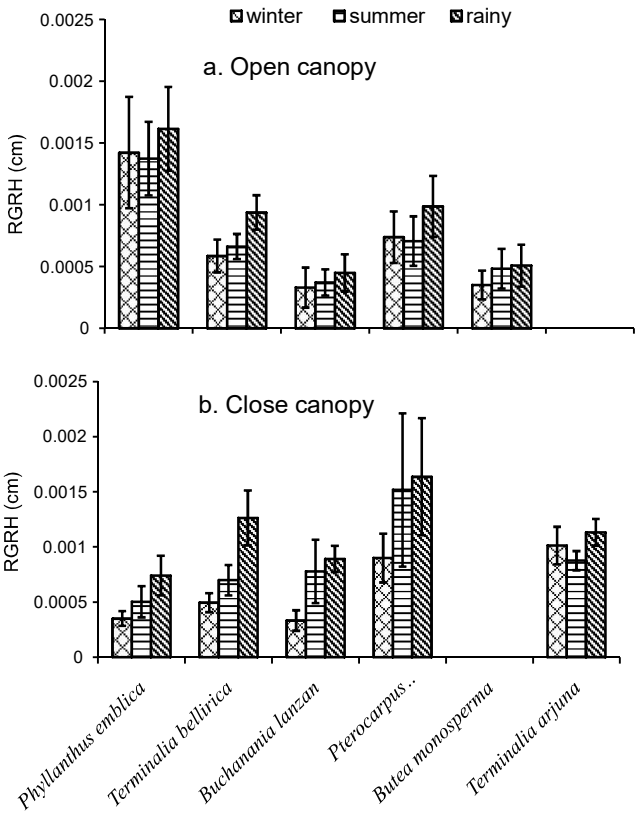

Fig. 3. RGRH of different species in different seasons under (a) open and (b) closed canopy conditions

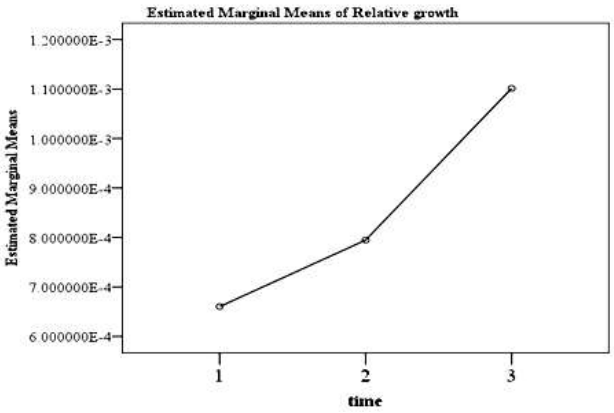

Fig. 4. Estimated marginal means of RGRH at three different time periods

higher RGRH under closed than under open canopy. *Buchanania lanzan* and *Terminalia bellirica* also had higher RGRH under closed canopy in at least one or two seasons. Under favourable growing conditions the relative growth rate of plant species varies considerably. Sapkota and Oden (2009) reported positive effects of canopy opening on relative growth in weight, height and radial growth due to reduced competition for light and space. Chacon and Armesto (2005) found six times greater RGR of seedlings under tree fall gap than under closed canopy.

Mean RGRH differed significantly at different time points or seasons (Fig. 4). In summer season (time 2) RGRH increased only slightly from winter season (time 1). However, a significant increase was noticed in rainy season (time 3) when RGRH increased to 0.00110127 cm. The availability of soil moisture is directly determined by pronounced seasonality of rainfall in the dry deciduous forests and plays a significant role in the germination, survival, and growth of tree seedlings (Khurana and Singh 2001, McLaren and McDonald 2003, Marod et al 2004). In the present investigation the relative growth rates of seedlings and saplings of all the six selected species were highest during the rainy season. The seedlings faced growth constraints in rainy seasons due to lower light availability under close canopy habitat in tropical dry forest resulting in decline in the physiological traits and RGR of light demanding pioneer species (Tripathi et al 2020). They also observed promotion in seedling survival under shady habitats in the dry deciduous forest during the driest summer season. Their observation can be linked with the survival of all the seedlings of *Terminalia arjuna* in the shaded area throughout the study period in the present study.

CONCLUSION

The results of present study emphasized that the species specific response plays a very important role in governing the seedling survival and relative growth of tropical dry deciduous tree species under variable canopy condition. The seasonal rainfall in the dry deciduous forest was another influencing factor that promoted the relative growth of tree seedlings. Large gaps in the forest are created due to commercial exploitation for timber; cutting and lopping for fuelwood creates small gaps; these gap formation favours the regeneration and survival of pioneer species. Seedlings of light demanding *Butea monosperma* survived only under open canopy while of shade tolerant non-pioneer *Terminalia arjuna* were restricted to the closed canopy areas. The environmental effects induced by canopy opening must be linked with the forest management. Long term study including more species could generate a thorough understanding of species specific strategy for survival and growth of tropical dry forest species in relation to canopy openings.

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